PATENT APPLICATION

PROGRAMMABLE APPLIANCE CONTROLLER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part application of U.S. Patent Application Serial No. 09/692,892, entitled "Two-Wire Appliance Power Controller", to Stanley S. Hirsh, et al., filed on October 19, 2000, issued as U.S. Patent No. 6,700,333 on March 2, 2004, and the specification thereof is incorporated herein by reference. That application claimed priority to U.S. Provisional Patent Application Serial No. 60/160,275, filed October 19, 1999, and the specification thereof is also incorporated herein by reference.

A related application entitled "Cordset Based Appliance Controller" is being filed concurrently herewith, to David C. Nemir, et al., Attorney Docket No. 70004-9601-CIP2, and the specification thereof is incorporated herein by reference.

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Not Applicable.

INCORPORATION BY REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

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Not Applicable.

BACKGROUND OF THE INVENTION

Field of the Invention (Technical Field):

The present invention relates to an electronic control which is completely incident within a cordset plug or plug-in module, and which enables the distributed control of an appliance. By offloading control functions from the appliance to the plug or module, the appliance itself becomes much simpler. The device represents a minimal control in that it uses very few parts, but has the advantage that it is programmable and may thus be adapted to a variety of control tasks. By implementing a programming approach that uses only three inputs, units may be built to stock and then programmed as needed, allowing for production economies of scale.

Description of Related Art:

Static electronic controls that are resident in the plug are well known. For example, U.S. Patent Nos. 4,853,822 (Kamijo) and 5,844,759 (Hirsh et al.) disclose electronic protective circuits that are disposed within an appliance plug and that are used to detect certain types of unsafe operating conditions, interrupting power in response thereto.

The present invention comprises a programmable electronic control which is completely incident within a cordset plug or plug-in module. By using internal electrostatic discharge protection diodes as power supply rectifying elements, a minimal implementation is achieved. Programming of the device is accomplished by only three total external connections, enabling a plug or module to be completely assembled and then programmed after the fact.

BRIEF SUMMARY OF THE INVENTION

The present invention is of an apparatus and method for control of an alternating current appliance, comprising: locating in either an appliance plug or a plug-in module programmable control means; and providing a plurality of electrical connections between the programmable control means and programming means. In the preferred embodiment, the plurality numbers no more than three. One programs the programmable control means via electronic signals from the programming means. A high

frequency signal is applied to two of the no more than three electrical connections to place the programmable control means into a programming mode. A series of pulses applied to two of the no more than three electrical connections is used to control both data and clock lines during programming. A mixture of direct current and alternating current signals applied to two of the no more than three electrical connections may also be employed to place the programmable control means into a programming mode. The programmable control means is electronically configured to implement a set of control actions, and preferably comprises a microcontroller, most preferably wherein the microcontroller controls a thyristor or transistor. The programming means is preferably operated after the programmable control means is completely assembled in the appliance plug or plug-in module. The invention provides for appliance function retrofit by programming the programmable control means to enable the appliance plug or plug-in module to implement a set of appliance control functions other than an originally intended set.

The invention is also of an apparatus for powering an electrical network, comprising internal electrostatic discharge protection diodes and excluding external rectification elements of a DC power supply for the electrical network, wherein the internal electrostatic discharge protection diodes perform the function of the external rectification elements. In the preferred embodiment, each of the internal electrostatic discharge protection diodes are paralleled by a MOSFET transistor that is enhanced to form an alternative conducting path around the internal electrostatic discharge protection diodes. The alternative conducting path allows firing of a thyristor during a portion of an AC cycle when said internal electrostatic discharge protection diodes are not conducting. The invention implements an enhancement of an internal MOSFET transistor that is in parallel with one of said internal electrostatic discharge protection, such that while applying the appropriate gate voltage to a thyristor the MOSFET ensures that the thyristor is turned on.

The present invention has the following objects and advantages:

a) it implements appliance control at the point where the appliance receives electrical power;

b) it may be implemented in the plug of an electric cordset;

c) it may be implemented in a plug-in module, into which an electric appliance is attached and thereby enabling a retrofit capability for an existing appliance;

d) it can use internal static protection diodes for power supply filtering, thereby removing the requirement for external power rectification diodes;

e) it is programmable; and

f) it may be programmed after the entire unit is assembled, by the use of no more than three external electrical connections, thereby allowing for assembly to be carried in bulk and programming to be carried out individually at a subsequent time, according to need.

Other objects, advantages and novel features, and further scope of applicability of the present invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawings, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The accompanying drawings, which are incorporated into and form a part of the specification, illustrate one or more embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The drawings are only for the purpose of illustrating one or more

preferred embodiments of the invention and are not to be construed as limiting the invention. In the drawings:

FIG. 1 is a block diagram depicting a specific embodiment of the present invention as implemented in a plug cap.

FIG. 2 depicts an alternative specific embodiment of the present invention as implemented in a module.

FIG. 3 depicts a specific embodiment of a microcontroller based controller.

FIG. 4 depicts the function of the internal static protection diodes.

FIG. 5 depicts the role of the internal static protection diodes as used for rectification.

FIG. 6 depicts the external components required for programming.

FIG. 7 depicts the state table for programming tasks.

FIG. 8 depicts a timing diagram for programming a sample bit stream.

<u>LIST OF REFERENCE NUMERALS</u>

20 - Electrical outlet

21 - Incoming hot conductor

22 - Hot prong of plug

23 - Neutral conductor

24 - Neutral prong of plug

26 - Controller

28 - Thyristor

30 - Power cord connected plug to appliance

32 - Plug

34 - Output of thyristor

35 - Outgoing hot conductor

36 - Conventional plug

40 - Appliance

44 - Gate of thyristor

46 - Microcontroller

48 - Bridge rectifier

50 - Filter capacitor

52 - Sense resistor

53 - Timing input

54 - Zener diode

56 - Thyristor control

58 - Sense input

60 - Power resistor

62 - Timing input

64 - Input/output pin of microcontroller

66 - Static protection diode

68 - Static protection diode

74 - P channel MOSFET transistor

76 - N channel MOSFET transistor

80 - Input buffer

82 - I/O pin

84 - I/O pin

86 - Chip common

90 - Data state storage capacitor

92 - Charge resistor

94 - Clock input during programming, sense input during operation

96 - Data input

98 - Capacitor

102 - Zener diode

104 - Inductor

106 - Blocking diode

108 - Logic one threshold

110 - Logic zero threshold

DETAILED DESCRIPTION OF THE INVENTION

The present invention is of a method and apparatus for implementing a programmable appliance control cordset or module. The device may be "built to stock", that is, it may be built as a generic article in large number without building in a specific feature set. Then, some quantity of devices may be programmed with specific features at a later date. In some implementations, the devices may even be reprogrammed at a subsequent date to deliver a different feature set. The advantage is that the cordset/module may be constructed as a generic article. The same unit may be assembled in large quantities but with programming, many different applications may be addressed.

FIG. 1 depicts a block diagram of one embodiment of the programmable controller of the present invention. The appliance power cord plug **32** is configured to be inserted into a wall outlet **20** in order to receive power. An electronic circuit comprising a controller **26** and thyristor **28** together with associated electronics as needed, is completely enclosed within plug **32**. Power delivery to the appliance **40** is controlled from within the plug **32** by means of the control of thyristor **28**. Controller **26** is resident within the plug **32** and determines whether or not (and when) to turn on thyristor **28**. Controller **26** turns on thyristor **28** by means of a control voltage applied to thyristor gate **44**. The controller **26** may receive commands from the appliance **30** or from the outlet **20** as described in co-pending applications.

FIG. 2 depicts a block diagram of a second embodiment of the programmable controller of the present invention. In this implementation, the appliance power cord is attached to a conventional plug **36** which does not have internal electronic components but is of standard construction. The conventional plug **36** is inserted into a module **42** which implements the control functions. The module **42** contains a controller **26** and thyristor **28** together with associated electronics as needed. In this way, the combination of conventional plug **36** and module **42** serves the same function as that of the electronic plug **32** in FIG. 1.

FIG. 3 depicts one embodiment for the electronic circuit inside the plug **32**. Although the following discussions assume a plug configuration, they could apply equally well to the module implementation depicted in FIG. 2. In FIG. 3, the incoming power lines are labeled as hot in **21** and neutral **23**. In a grounded neutral electrical system, the so-called "hot" conductor is ungrounded while the "neutral" conductor is connected to earth ground somewhere within the electrical system. In the present application, the distinction between hot and neutral is immaterial and in some embodiments, the two could be transposed with no loss of function. An alternating current source voltage is applied to conductors **21** and **23**. In the U.S., this is generally a 120 volt rms sinusoidal supply that has a frequency of 60 hertz, although the circuit could be used with other power sources. Control actions are taken by a microcontroller **46** which is a device which may be programmed to carry out various control algorithms. Resistor **60** is a power supply resistor which furnishes power to the microcontroller directly from the neutral line **23**. Bridge rectifier **48** serves to convert the alternating current source voltage into a direct current voltage and this DC voltage is filtered by capacitor **50** and regulated by zener diode **54** to provide the power supply voltage for microcontroller **46**. The microcontroller **46** controls thyristor **28** by output line **56**. The microcontroller **46** receives timing information (the state of the AC power line) from timing input **62**. The microcontroller **46** receives information about the load from sense input **58**. Although not depicted in FIG. 3, all microcontrollers must have a clock, either internal or external, to control the sequencing of instructions. For many microcontrollers, the clock will be internal and, accordingly, no external clock or oscillator is depicted in FIG. 3.

It should be noted that there are effectively three external electrical connections connecting to plug **32**, namely incoming hot conductor **21**, outgoing hot conductor **35** and neutral **23**. Although the neutral conductor **23** is depicted as being connected to plug **32** in two places, electrically, it is regarded as a single conductor.

FIG. 4 depicts the internal static protection diodes that are built into many commercially available microcontrollers. By making use of the electrostatic discharge (ESD) protection diodes that are commonly built into the input-output (I/O) pins of off-the-shelf complementary metal oxide (CMOS) integrated circuits, including CMOS microcontrollers, the circuit of FIG. 3 may be simplified. Such simplifications are important in order to arrive at the absolute minimum parts count and consequently the absolute minimum cost. FIG. 4 depicts an I/O pin **64** and the associated internal ESD diodes **66,68**, input buffer **80** and output drivers **74,76**. In a CMOS microcontroller, the I/O pins are generally internally selectable under program control to be either high impedance (using buffer **80**) inputs or to be output drivers. If a given I/O pin is chosen to be an output, then the MOSFET transistors **74** and **76** are used to drive the output to either the positive power supply potential Vdd or to the negative power supply potential Vss. Diode **66** serves to clamp I/O pin **64** to the Vdd power supply bus that is internal to the microcontroller. In other words, diode **66** serves as a low impedance path to Vdd in case a high voltage potential is applied to an I/O pin, thereby protecting transistor **74** from being destroyed due to unintentional electrostatic discharge. In a similar way, internal diode **68** serves to clamp I/O pin **64** to the Vss bus in the case that a potential that is more negative than Vss is applied, and thereby protecting transistor **76** from being damaged.

By applying a current limited AC waveform between two ESD protected I/O pins on a microcontroller, the internal ESD diodes can be used to implement a full wave bridge rectifier. In other words, ESD diodes that are already internally present in many CMOS integrated circuits, and in particular, in most CMOS microcontrollers, may be used to replace the external rectification elements that were depicted in FIG. 3.

FIG. 5 depicts an implementation of the appliance controller that makes use of the internal static protection diodes to implement the power supply. The incoming hot conductor **21** is connected directly to an input/output pin **82**. The neutral conductor **23** is connected to an input/output pin **84** through a power resistor **60.** Internal to the microcontroller **46,** the ESD diodes serve to make a connection to the microcontroller **46** power supply pins denoted as Vdd and Vss. The filter capacitor **50** serves to filter and zener diode **54** serves to regulate the DC power supply as discussed in conjunction with FIG. 3. Moving the rectification elements to be internal to the microcontroller allows for circuit simplification since the microcontroller already has built-in static protection diodes. Omitting the external rectification diodes enables the programming of the microcontroller via minimal external electrical connections as will be discussed in conjunction with FIG. 6.

Once the power supply voltage has been established, the ESD diodes only conduct during the interval when the applied AC voltage is greater than the sum of the power supply voltage plus the voltage drops of the ESD diodes. Because of this, gate current for turning on thyristor **28** (via control line **56**) would normally only be available while one of the ESD diodes is conducting to form a conduction path for the gate circuit. This is satisfied for most of each half cycle, but not near the zero crossings. To allow gate current anywhere, even at the zero crossing, an alternate conduction path must be provided around each of the ESD diodes. This is accomplished by enhancing the MOSFET transistor (refer to FIG. 4) that is in parallel to the diode that would conduct to the hot conductor **21**, while applying the appropriate gate voltage to the thyristor **28**. The gate circuit for the thyristor is now completed with gate current being provided by the filter capacitor **50**. By synchronously controlling the AC input port and the thyristor gate control **56**, the present invention can implement synchronous rectification as well as having complete control over the thyristor **28**.

FIG. 6 depicts a preferred embodiment wherein programming may be accomplished by the use of only the three external electrical connections that are available in the assembled unit, namely, common (or neutral), input and output. In FIG. 6, the plug **32**, is shown as having four external electrical connections, of which only three, namely **21**, **23** and **35** are unique (since the neutral conductor **23** is

simply a pass through connection). The microcontroller **46** may represent any standard CMOS based microcontroller such as the 12C508 style of one time programmable device or the 12F629 style of flash programmable device, both of which are manufactured by the Microchip Corporation. As described in conjunction with FIG. 5, two connections, **82** and **84**, are used to develop a DC power supply voltage and to charge power supply capacitor **50**. Capacitor **50** is chosen to be of a sufficient size to maintain the power supply voltage for short intervals of time, even in the absence of applied power.

In order to place microcontroller **46** into a programming mode, the programming line **88** must be pulled to a voltage that, referenced to Vss, is substantially higher than Vdd. In order to do this, a charge pump has been added that consists of diode **106** and capacitor **98**. This serves as a means to apply a high voltage to programming line **88**. Due to the fact that the internal ESD diodes will clamp line **82** to within a diode drop of the Vdd level, it is preferred to add inductor **104** in series with input **82.** Inductor **104** serves as a so-called "choke". Inductors have an impedance that is proportional to frequency. Inductor **104** is chosen so as to have a low impedance at 60 hertz input so that it will not result in a substantial voltage drop during normal operation. However, during programming, it is desirable to apply a high frequency AC wave across lines **21** and **23** to charge up capacitor **98** through resistor **100**. By choosing an excitation of, perhaps, 60 KHz, the AC impedance of inductor **104** is increased by a factor of one thousand and serves to block this high frequency signal. So, during programming only, by applying a signal of $V_1 + V_2\sin(\omega t)$ volts across lines **21** and **23,** where V1 and V2 are constant voltages and ω is a high frequency relative to 60 Hz, it is possible to both maintain a voltage Vdd on power supply capacitor **50** (through the DC component V_1) and to maintain a voltage on programming capacitor **98** that is higher than Vdd. It should be noted that in FIG. 6, the voltage reference for programming and operation of microcontroller **46** is the common **86** which has a potential of Vss.

During normal operation, the voltage across lines **21** and **23** will be either 50 Hz or 60 Hz, which is a sufficiently low frequency that inductor **104** acts like a short circuit. In this case, due to the internal ESD diodes within the microcontroller **46**, capacitor **98** will be charged to a value that is close to Vdd.

When the programming line **88** is held to a voltage that is substantially higher than the power supply value, Vdd, the microcontroller **46** is placed into a programming mode. During that time, programming signals called data and clock (lines **94** and **96)** may be used to store a computer program into microcontroller **46**.

It should be noted that there are alternative means for generating a relatively high voltage at programming line **88**. One such means does not require an inductor. Instead, by capacitively coupling programming line **88** to the neutral **23**, it is possible to develop the required voltage level using a charge pump. As in the circuit in FIG. 6, the key idea is that by applying a mixture of AC and DC signals between conductors **21** and **23**, it is possible to both deliver power to the microcontroller, as well as generate a programming control signal. By taking care to avoid using signals (eg: 120 volts RMS at 60 Hz) that are likely during normal operation, programming may be accomplished without concern that an accidental programming event might occur during normal appliance operation.

During programming, thyristor gate **56** is in a high impedance condition and thyristor **28** is turned off. This serves to isolate conductors **21** and **35** so that during programming, signals imposed upon one side of the thyristor **28** do not impact the other side. Capacitor **90** serves to hold the voltage state on the data input **96** for short intervals, regardless of the value of the clock line **94**. This allows for both clock and data signals to be implemented from line **35** through the resistor **52**. Different microcontrollers will have different programming sequences, but an examination of one specific case is easily transferred into the general case. Suppose that the microcontroller **46** recognizes the data on line **96** whenever the clock line **94** goes from a high to a low state (a so-called falling edge trigger). So, the clock will always end up in a low state (logic zero) after programming each data bit. There are four programming possibilities as enumerated in FIG. 7.

As depicted in FIG. 7, if the initial data state (as defined by the state of charge on capacitor **90)** is the same as the data bit that it is to be programmed, then the clock state, as defined by the voltage imposed on conductor **35**, is brought to a high state, then a low state over a time interval that is

sufficiently short that it does not cause capacitor **90** to change state. If the initial data state is a zero (corresponding to a discharged capacitor **90**), and it is desirable to program a data bit of one, then the clock line **94** is pulled high for a time interval that is sufficient to charge capacitor **90** to a binary one level. Then the clock makes a low going transition to program the data value of one. If the initial data state is one and it is desirable to program a zero, then the clock line is left in a low state for a sufficient period of time to ensure that the capacitor **90** discharges. Then the clock line makes a high, then a low transition to program the data value of zero. Note that programming may take place asynchronously, since it is quicker to program a data bit if a state change is not required. Alternatively, programming could be designed to take a known amount of time for each bit by discharging the capacitor **50** after each bit is programmed and always starting from a state of zero (corresponding to the first two rows in FIG. 7).

FIG. 8 depicts the timing diagram for asynchronously programming the bit sequence 0011010. Notice that the data line has a voltage value that is stored on a capacitor. This capacitor may be charged and discharged with a time constant (which will be determined by the capacitor value as well as clock voltage and limiting resistors). Whenever the clock is in the high state, it charges the data line. In the low state it discharges the data line. If the voltage on the data line has a value higher than some threshold **108** when the clock signal makes a low going transition, this will be recognized as a "one". If the voltage on the data line has a value lower than some threshold **110** when the clock signal makes a low going transition, this is recognized as a "zero". The values of thresholds **108** and **110** are characteristic to the specific microcontroller type.

Although FIG. 6 depicts the elements required for programming, after programming, plug **32** may be used as a part of a control appliance. In particular, the clock line **94** may now be used for sensing the state of a load that is attached to conductor **35**. The data line **96** could be set to be a tristate input and would have no use in the normal operation of the device. A key implication of the construction depicted in FIG. 6 is that all electronic circuitry can be assembled into a plug or module and completely covered in plastic or other insulating material. It is not necessary to have access to the

internal circuitry in order to program the device. Instead, by simply making use of the inputs (which are at the plug prongs) and the hot output (**35** in FIG 6), programming may be accomplished at a later date. This has favorable implications for manufacturing. It may be desirable for a cordset that is used for electric lamps to have a different program than a cordset that is used for electric fans. However, the electronic assembly (the "hardware") is identical for both products. By having the ability to program the device after construction, appliance cords can be built in bulk without programming and placed into inventory. Then, prior to shipment, they can be programmed with the correct sequence of instructions. In a similar way, modules that are designed to implement lamp dimming or lamp fading or automatic lamp turn off can be manufactured at the same time and in the same way and then programmed at some time after assembly to be a dimmer, a fader or an automatic turn-off.

As configured in module form, the present invention allows a means for retrofit of an existing appliances. By adding an appropriately programmed module to the plug of an appliance, the control configuration may be modified. So, for example, if an appliance was designed to behave in a certain manner, through the addition of an appropriately configured module, it might be possible to modify the behavior to have a different function.

Although the invention has been described in detail with particular reference to these preferred embodiments, other embodiments can achieve the same results. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover in the appended claims all such modifications and equivalents. The entire disclosures of all references, applications, patents, and publications cited above are hereby incorporated by reference.